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ORIGINAL ARTICLE

Comparative clinical outcomes after thymectomy for myasthenia gravis: Thoracoscopic versus trans-sternal approach

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KEYWORDS
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Summary *Background:* Thymectomy is an effective treatment option for long-term remission of myasthenia gravis. The superiority of the trans-sternal and thoracoscopic surgical approaches is still being debated. The aims of this study are to compare postoperative outcomes and neurologic outcomes between the two approaches and to identify prognostic factors for complete stable remission (CSR).

Methods: Myasthenia gravis patients who underwent thymectomy with trans-sternal or thoracoscopic approach in MahaRaj Nakorn Chiang Mai Hospital, Chiang Mai, Thailand between January1, 2006 and December 31, 2013 were retrospectively reviewed. The endpoints were postoperative outcomes and cumulative incidence function for CSR. The analysis was performed using multilevel model, Cox's proportional hazard model, and propensity score.

Results: Ninety-eight patients were enrolled in this study: 53 in the thoracoscopic group and 45 in the trans-sternal group. There were no significant differences between groups in composite postoperative complications, surgical time, ventilator support days, and length of intensive care unit stay. Intraoperative blood loss and length of hospital stay were significant less in

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the thoracoscopic group. The CSR and median time to remission were not significantly different between the two approaches. Prognostic factors for CSR were nonthymoma (hazard ratio: 3.5, 95% confidence interval: 1.01—12.22) and presence of pharmacological remission (hazard ratio: 24.3, 95% confidence interval: 3.27—180.41).
Conclusion: Thoracoscopic thymectomy is safe and provides good neurologic outcomes in comparison to the trans-sternal approach. Two predictive factors should be considered for CSR. Further prospective studies with a larger sample size and longer follow-up period are warranted to confirm these results.

1. Introduction

Myasthenia Gravis (MG) is an auto-immune disease associated with abnormal antibodies binding to the acetylcholine receptors at the neuromuscular junction of the skeletal muscle and causing the destruction and modification of the neuromuscular junction.[1] MG patients usually present with a fluctuating degree of weakness of the skeletal muscle, e.g., ocular, bulbar, respiratory muscles, and extremities.[2]

MG is strongly associated with thymic abnormalities. About 10—21% of myasthenia patients have thymoma and 65—70% of those have thymic hyperplasia,[3,4] whereas 20—47% of patients with a thymoma have MG.[5—7] Previous studies reported that 40—90% of MG patients achieved remission after thymetomy versus 10—20% of those on medication alone.[8,9] Thymectomy can be completed according to several approaches: trans-sternal, transcervical, thoracoscopic, and subxyphoid. Trans-sternal thymectomy has been the treatment of choice for MG patients according to the Myasthenia Gravis Foundation of America (MGFA). Recently, the thoracoscopic approach is not only widely performed in early stage nonsmall cell lung cancer,[10—13] but also in thymectomy because of less pain, smaller scarring, shorter length of hospital stay, and lower incidence of myasthenia crisis in comparison to the trans-sternal approach.[14] Moreover, the rate of complete stable remission (CSR) is not inferior to what is obtained with the trans-sternal approach.[15—18]

In our institute, thoracoscopic thymectomy has been performed since 2006. There are no reports on the comparative effectiveness between the two approaches in Thailand. Therefore, this study was conducted to compare postoperative outcomes and long-term neurologic outcomes between thoracoscopic and trans-sternal approaches.

2. Methods

This study is a retrospective cohort study of MG patients who underwent trans-sternal or thoracoscopic thymectomy between January 1, 2006 and December 31, 2013 at Maharaj Nakorn Chiang Mai Hospital, Chiang Mai University, Chiang Mai, Thailand. All patients were diagnosed by neurologists using the MGFA clinical classification.[19] Contrasted computed tomography (CT) scan was performed in all cases. Thymoma or malignant thymoma were diagnosed and evaluated by expert thoracic radiologists from our institute, using published criteria based on a CT scan. The tumor can be identified as invasive by imaging that show invasion of the surrounding tissue or great vessels.[20] Preoperative blood antiacetylcholine receptor antibody titers were not performed. The primary endpoint of this secondary analysis was postoperative outcomes [operative time, blood loss, composite postoperative complications, length of intensive care unit (ICU) and hospital stay, intubation time, 28-day mortality]. The composite postoperative complications include all postoperative complications (diaphragmatic paralysis due to phrenic nerve injury, atelectasis, cholinergic crisis, myasthenic crisis, reintubation, and pneumonia). The secondary endpoint was CSR defined as no signs or symptoms of MG and no therapy for at least 1 year after surgery, except for isolated weakness of eyelid closure.[19] This study was reviewed and approved by the Research Ethics Committee, Faculty of Medicine, Chiang Mai University.

2.1. Surgical techniques

In our institute, selection criteria for thoracoscopic approach for MG are one of following: (1) nonthymomatous patients; or (2) small ($<$ 3 cm) intrathymic thymoma.[21,22] Trans-sternal thymectomy was performed with the standard technique. Thoracoscopic approach was performed through the right side with three small incisions under general anesthesia with isolated lung ventilation. The patient was placed in the left lateral decubitus position and slightly supine, about 30°. Right arm was abducted about 120° and the elbow was flexed over a padded L-screen for exposure. A camera port was placed at the eight intercostal space midaxillary line, and two working ports were placed at the fourth intercostal space at the anterior axillary line and sixth intercostal space at the posterior axillary line. Prepericardial fat above the right phrenic nerve was dissected. Thymic tissue and all anterior mediastinal fat were also dissected away 1 cm anterior to the left phrenic nerve. Arterial supplies and venous drainage were ligated with metallic clips. Bilateral superior horns were dissected with blunt technique. Thymus tissue and prepericardial fat pad on left side were removed as much as possible or at least reaching to left pleura. A right chest drain was placed in the right pleural space. Extubation was performed immediately after operation, in the recovery room or in the intensive care unit depending on the consideration of the anesthesiologists.

In cases of left side tumor, especially if $>$ 3 cm, we performed a trans-sternal approach. If the tumor was well

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capsulated and < 3 cm, the thoracoscopic approach was used first. If the tumor was difficult to dissect, we converted to a trans-sternal approach. However, in this study, only the right sided-approach was performed, and no conversions were reported.

2.2. Data analysis

Categorical data were presented as frequency and percent. Fisher's exact test was used to compare categorical variables. Continuous data were presented as mean and standard deviation or median and interquartile range depending on data distribution. Student *t* test or Wilcoxon's rank-sum test was used to compare continuous variables. Two-step analysis was performed. Logistic regression was used to calculate a propensity score (PS), which evaluates confounding by indication. The variables included in the model for PS were age, sex, MGFA classification, time to surgery, preoperative medication, myasthenic crisis within 1 month before surgery, preoperative plasmapheresis, preoperative conditions, preoperative forced vital capacity, and preoperative CT findings; the score was then divided into quintiles, called PS-groups. A multilevel model stratified by PS-groups was used for comparing the primary endpoint between groups. For the secondary endpoint, firstly, a univariable cox's regression analysis for all variables was performed, and variables having a p value < 0.1 were included in the multivariable model with and without stratification by PS-groups to identify independent prognostic factors for CSR. A multicollinearity test was done. A p value < 0.05 was considered to be statistically significant. The Kaplan–Meier failure estimate curve was used to demonstrate cumulative incidence function for CSR and to compare the two groups. All statistically analysis was performed using STATA program version 13.0 (StataCorp, CS, TX, USA).

3. Results

Ninety-eight MG patients were enrolled in this study, 68 men (69%) and 30 women (31%); 53 patients (54.1%) underwent thymectomy by thoracoscopic approach and 45 patients (45.9%) by trans-sternal approach. Demographic and preoperative data are shown in Table 1. There was no significant difference in terms of comorbid diseases except for hypertension, severity of disease, preoperative plasmaphreresis, operative parameters, and medication. The trans-sternal group had more patients with hypertension than in the thoracoscopic group. According to the preoperative CT scan, the number of patients who had thymoma was significant higher in the trans-sternal group than the thoracoscopic group. However, the PS (probability of receiving certain treatment) showed a statistically significant difference, therefore the overall preoperative patient characteristics in each treatment group were different. For this reason, a multilevel model stratified by PS-groups to identify postoperative outcomes was performed (Table 2).

Perioperative findings and postoperative conditions are reported in Table 3. The mean operative time was not significantly different between groups. Patients in the trans-sternal group had more intraoperative blood loss than patients in the thoracoscopic group.

Postoperative complications occurred in 12 patients: four patients in the trans-sternal group had left diaphragmatic paralysis and all of them were diagnosed with malignant thymoma, two patients in each group had atelectasis, one of which in the trans-sternal group required reintubation; one patient in the trans-sternal group had cholinergic crisis, one patient in each group had a MG crisis, and one patient in the thoracoscopic group had pneumonia. No in-hospital mortality was observed in this study. Most of the patients in this study had no postoperative complications (89%) and could be immediately extubated postoperatively (86%). There was no difference in the length of ICU stay and ventilator support time between the two groups, although the trans-sternal group had a significantly longer median length of hospital stay than the thoracoscopic group. There was no statistically significant difference between groups in the duration of ventilator support. Only three patients needed ventilator support in the thoracoscopic group (1 day, 6 days, and 39 days, respectively), whereas, 11 patients in the trans-sternal group needed it; five patients for 1 day, one patient for 2 days, one for 6 days, one for 13 days, one for 20 days, one for 39 days, and one for 40 days.

Study of postoperative outcomes analyzed by multilevel model stratified by PS-groups (Table 2) showed no significant differences between groups in terms of composite postoperative complications, surgical time, ventilator support day, and length of ICU stay. Intraoperative blood loss and length of hospital stay were significant less in the thoracoscopic group.

For pathology results, because the mean age of the patient cohort was around 40 years, the most common thymic pathology finding was fatty involution, not thymic hyperplasia.[23]

The most common thymus pathology was fatty involution (44 out of 98 cases, 45%; Table 4). The incidence of MG associated with thymoma in this study was 29.6% (29 out of 98 cases). The number of patients diagnosed with fatty involution was significantly higher in the thoracoscopic group than in the trans-sternal group, whereas the number of patients diagnosed with thymoma was higher in the trans-sternal group. There were two patients diagnosed with malignant thymoma in the thoracoscopic group, but their preoperative CT finding reported thymic hyperplasia and small-sized thymoma.

For the neurological outcomes after thymectomy, 27 of 98 patients (27.6%) had CSR at the most recent follow-up, 46 patients (46.9%) had pharmacological remission (PR), and 20 patients (43.5%) had no CSR. The comparison of neurological outcomes is shown in Table 5. The number of patients who had medical reduction, achieved PR, and achieved CSR were not significantly different between the two groups. The median time at all events and the MGFA classification at the end of follow-up were not different between groups. The cumulative incidence function of CSR at 48 months and 96 months was slightly higher in the thoracoscopic group (27.07% vs. 19.24% and 60.38% vs. 40.88%, respectively, $p = 0.268$; Figure 1). The median follow-up time and long-term survival were not different between groups. For long-term mortality, of the eight patients who died, two had thymoma and five had malignant thymoma. In the thoracoscopic group, two patients (1

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thymoma and 1 malignant thymoma) died from a myasthenic crisis with septic shock at 4.6 years and 1.9 years after surgery. In the trans-sternal group, two patients (malignant thymoma) died from febrile neutropenia, severe community acquired-pneumonia with septic shock at 6 months and 1 year after surgery, two patients (malignant thymoma) died from a myasthenic crisis and septic shock at 1.5 months and 4.6 months after surgery, and two patients (1 thymoma and 1 fatty involution) died from myasthenic crisis with community acquired-pneumonia at 10 years and 10.3 years after surgery.

The identification of prognostic factors for CSR after thymectomy is shown in Table 6. The presence of PR and nonthymoma status were significant independent prognostic factors for CSR. However, after stratification by PS, only PR was an independent prognostic factor for CSR. The cumulative incidence function of CSR stratified by PR and thymoma are shown in Figure 2. In the subgroup analysis of nonthymoma patients (69 patients), no independent prognostic factor for CSR was found, possibly because of the small sample size (low statistical power).

4. Discussion

In 1987, after Kirschner[24] reported the improvement of clinical symptoms of MG after thymectomy, first performed by Alfred Blalock in 1941,[25] it has been widely accepted as

Table 1 Patient's characteristics.

Variables	Thoracoscopic group ($n = 53$)	Transsternal group ($n = 45$)	p
Sex			0.190
Female	13 (24.5)	17 (37.8)	
Male	40 (75.5)	28 (62.2)	
Age (y)	41.5 ± 14.2	38.9 ± 14.9	0.388
Underlying disease			
Diabetes mellitus	9 (17.0)	4 (8.9)	0.371
Hypertension	1 (1.9)	8 (17.8)	0.011
Dyslipidemia	3 (5.7)	4 (8.9)	0.700
Thyroid disease	6 (11.3)	2 (4.4)	0.282
Others	3 (5.7)	2 (4.4)	1.000
MGFA classification			0.699
I	3 (5.7)	4 (8.9)	
IIa	17 (32.1)	10 (22.2)	
IIb	28 (52.8)	23 (51.1)	
IIIa	0	1 (2.2)	
IIIb	4 (7.5)	5 (11.1)	
IV	0	0	
V	1 (1.9)	2 (4.5)	
Time to surgery (mo)	12 ± 31(1–192)	11 ± 21 (1–48)	0.359
Preoperative prednisolone (mg)	20 ± 35 (0–60)	30 ± 35 (0–60)	0.100
Preoperative mestinon (mg)	180 ± 120 (0–540)	240 ± 60 (0–540)	0.188
Preoperative azathioprine (mg)	25 ± 75 (0–100)	0 ± 50 (0–150)	0.123
Myasthenic crisis within 1 mo before surgery	5 (9.4)	8 (17.8)	0.248
Preoperative plasmapheresis	12 (22.6)	17 (37.8)	0.123
Preoperative conditions			
Respiratory failure	13 (24.5)	16 (35.6)	0.271
Bulbar involvement	36 (67.9)	36 (80.0)	0.251
Ocular involvement	49 (92.5)	43 (95.6)	0.684
Preoperative FVC	1790.5 ± 655.6	1582 ± 957.3	0.465
Preoperative CT findings			0.008
No mass	21 (39.6)	10 (22.2)	
Thymic hyperplasia	13 (24.5)	6 (13.3)	
Thymoma	19 (35.9)	22 (48.9)	
Thymic cyst	0	4 (8.9)	
Malignant thymoma	0	3 (6.6)	
Probability of receiving a certain treatment (propensity score)[a]	0.68 ± 0.20	0.38 ± 0.26	<0.001

Data are presented as n (%), mean ± SD, or median ± IQR (min–max).
CT = computed tomography; FVC = forced vital capacity; IQR = interquartile range; max = maximum; min = minimum; MGFA = Myasthenia Gravis Foundation of America; SD = standard deviation.
[a] Propensity score calculated by logistic regression analysis considering sex, age, underlying disease, MGFA classification, time to surgery, preoperative medication, myasthenic crisis within 1 month before surgery, preoperative plasmapheresis, preoperative conditions, preoperative FVC, and preoperative CT findings as determinants of undergoing a thoracoscopic approach.

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Table 2 Postoperative outcomes of the thoracoscopic group compared with the trans-sternal group: multilevel model stratified by propensity score.

Variables	Risk ratio	Mean difference	95% CI	*p*
Surgical time (min)	—	9.93	−.33 to 26.19	0.231
Blood loss	—	−60.43	−102.74 to −18.11	<0.001
Composite postoperative complications	0.5		0.14−1.66	0.249
Ventilator support d (d)	—	−1.13	−3.53 to 1.27	0.355
Lengths of ICU stay (d)	—	−0.10	−0.42 to 0.21	0.521
Lengths of hospital stay (d)	—	−0.30	−0.42 to −0.17	<0.001

CI = confidence interval; ICU = intensive care unit.

Table 3 Perioperative finding and postoperative conditions in the two groups.

Variable	Thoracoscopic group ($n = 53$)	Transsternal group ($n = 45$)	*p*
Perioperative findings			
Surgical time (min)	150.4 ± 34.9	140.4 ± 47.8	0.239
Blood loss (mL)	50 ± 50 (0−300)	100 ± 150 (0−600)	0.005
Postoperative conditions			
No complication	49 (92.5)	38 (84.4)	0.336
Immediate extubation	48 (90.6)[a]	36 (80.0)	0.158
Left diaphragm paralysis	0	4 (8.9)	0.041
Atelectasis	2 (3.8)	2 (4.4)	1.000
Cholinergic crisis	0	1 (2.2)	0.459
Myasthenic crisis	1(1.9)	1 (2.2)	1.000
Reintubation	0	1 (2.2)	0.459
Pneumonia	1 (1.9)	0	1.000
ICU stay (d)	0 ± 0 (0−39)	0 ± 1 (0−40)	0.519
No ICU needed	41 (77.4)	32 (71.1)	0.521
Ventilator support (d)	6 ± 38 (1−39) $n = 3$	2 ± 12 (1−40) $n = 11$	0.570
Length of hospital stay (d)	7 ± 4 (4−38)	10 ± 4 (5−65)	<0.001

Data are presented as *n* (%), mean ± SD, or median ± IQR (min−max).
ICU = intensive care unit; IQR = interquartile range; max = maximum; min = minimum; SD = standard deviation.
[a] Two patients were extubated at recovery room.

Table 4 Pathologic report.

Variables	Thoracoscopic group ($n = 53$)	Transsternal group ($n = 45$)	*p*
Pathologic reports			0.005
Fatty involution	31 (58.5)	13 (28.9)	
Thymic hyperplasia	8 (15.1)	4 (8.9)	
Thymoma	6 (11.3)	10 (22.2)	
Malignant thymoma	2 (3.8)	11 (24.5)	
Thymic involution	5 (9.4)	5 (11.1)	
Thymic tissue	1 (1.9)	2 (4.4)	

Data are presented as *n* (%).

standard treatment of MG in addition to medical treatment. The results of the most recently published randomized trial demonstrated that extended trans-sternal thymectomy plus alternate day prednisone improved clinical outcomes over a 3-year period in comparison to alternate day prednisone alone in patients with nonthymomatous MG.[26] Many previous studies reported that thymectomy in MG can achieve CSR.[27−29] Over the years, CSR rate progressively increased from 27−37.4% to 37−58.2% and 46−75% at 3 years, 10 years, and 15 years of follow-up, respectively.[28,30,31] There are several approaches for thymectomy: trans-sternal, transcervical, unilateral thoracoscopic, bilateral thoracoscopic, subxyphoid single portal, all with comparable

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Table 5 Neurological outcomes after thymectomy.

Variables	Thoracoscopic group ($n = 53$)	Transsternal group ($n = 45$)	p
Decreased medication	47 (88.7)	40 (88.9)	1.000
Median time of decreased medication (mo)	2.2 ± 3.3 (0.1–76.6)	1.4 ± 3.3 (0.5–26.1)	0.375[a]
Pharmacologic remission	27 (50.9)	19 (42.2)	0.422
Median time of pharmacologic remission (mo)	3.2 ± 26.8 (0.5–76.8)	6.5 ± 17.8 (0.7–110.4)	0.780[a]
Complete stable remission (CSR)	15 (28.3)	12 (26.7)	1.000
Median time of CSR (mo)	36.5 ± 44.4 (8.7–76.8)	34.7 ± 62.8 (8.3–110.4)	0.283[a]
MGFA at the end of follow-up			0.764
I	14 (26.4)	12 (26.7)	
IIa	27 (50.9)	18 (40.0)	
IIb	8 (15.1)	11 (24.5)	
IIIa	2 (3.8)	2 (4.4)	
Unknown	2 (3.8)	2 (4.4)	
Follow-up time (mo)			0.128[a]
Mean ± SD	41.8 ± 29.9	54.9 ± 39.3	
Median ± IQR	38.8 ± 43.0	56.1 ± 64.1	
Min–Max	0.3–118.5	0.3–125.2	
Loss to follow-up	7 (13.2)	7 (15.6)	0.779
Death	2 (3.8)	6 (13.3)	0.18

Data are presented as n (%), mean ± SD, or median ± IQR (min–max).
IQR = interquartile range; max = maximum; min = minimum; MGFA = Myasthenia Gravis Foundation of America; SD = standard deviation.
[a] Log-rank test.

outcomes.[14–16,18,32,33] In the past, the most accepted approach as standard technique was trans-sternal thymectomy; however, after introducing thoracoscopic thymectomy, this became the major approach for thymectomy in MG patients because of the many advantages. However, there are still discussions on the best side of approach, and on unilaterality or bilaterality. In our institute, we perform unilateral thoracoscopic thymectomy via the right-sided approach because of several reasons. Firstly, the right thoracic cavity is larger than the left side; therefore, it is easier for dissection of the thymus gland. Secondly, superior vena cava is more clearly identified at the right side, so it is rarely injured. Finally, superior vena cava is an excellent landmark to identify the innominate vein as well as the venous tributaries to the thymus grand. Liu et al[33] compared the long term outcomes of unilateral video-assisted thoracic surgery extended thymectomy with the bilateral approach in nonthymomatous MG and reported that the unilateral approach had long-term CSR comparable to the bilateral approach.

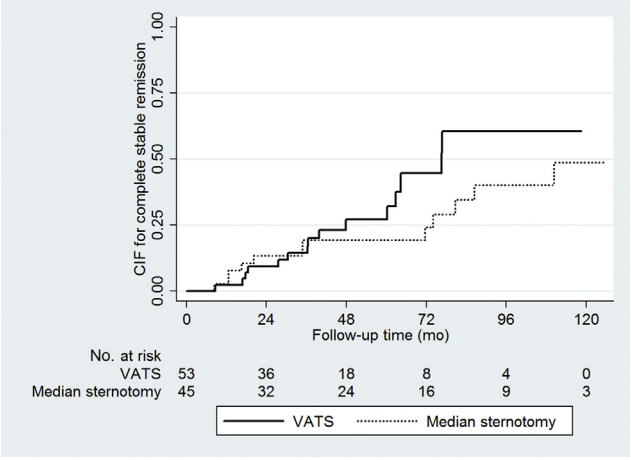

Figure 1 Cumulative incidence function (CIF) of complete stable remission comparing between the two approaches ($p = 0.268$). VATS = video-assisted thoracoscopic surgery.

Preoperative CT scans showed a significant higher number of thymoma patients in the trans-sternal group. In clinical practice, the trans-sternal approach is standard. However, for small thymomas less than 5 cm without surrounding tissue invasion or Masaoka Class I or II, the thoracoscopic approach was accepted.[14,34–36] In our institute, if the thymoma was identified by preoperative CT scan, the trans-sternal approach was preferred to the thoracoscopic approach. This could be a confounder by indication in the present analysis.

From the perioperative data, the surgical time was slightly longer in the thoracoscopic group than in the trans-sternal group; whereas the thoracoscopic group had a significantly less amount of blood loss than the trans-sternal group. The reason might be that the trans-sternal approach has larger incisions and requires the division of the sternum. Moreover, the patients in the trans-sternal group had a thymoma more frequently, and in some cases this needs a more aggressive dissection such as *en-bloc* resection. The amount of blood loss recorded in our study was rather small in comparison to previous studies.[33,37,38] In our study, a left diaphragmatic paralysis was found only in the trans-sternal group cases that were diagnosed with malignant thymoma; therefore, it might have occurred when dissecting the tumor away from the phrenic nerve. The length of hospital stay was significant longer in the trans-sternal group, something that could be due to a more aggressive operation or dissection.

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Table 6 Prognostic factors for complete stable remission after thymectomy analyzed by univariable and multivariable Cox's regression analysis.

Variables	Univariable analysis			Multivariable analysis		
	HR	95% CI	*p*	HR	95% CI	*p*
Age < 40 y	2.3	1.04–4.91	0.037	2.1	0.96–4.61	0.062
				2.0[a]	0.78–4.97[a]	0.151[a]
Female	3.0	0.90–9.97	0.073	1.6	0.47–5.12	0.453
				1.7[a]	0.45–6.17[a]	0.442[a]
Nonthymoma	4.2	1.24–13.98	0.021	3.5	1.01–12.22	0.049
				3.2[a]	0.72–13.98[a]	0.126[a]
Pharmacological remission	29.6	4.01–218.80	0.001	24.3	3.27–180.41	0.002
				21.8[a]	2.90–162.78[a]	0.003[a]
DM	1.1	0.32–5.59	0.906	—	—	—
Hypertension	1.1	0.27–4.85	0.855	—	—	—
Dyslipidemia	0.6	0.08–4.24	0.587	—	—	—
Thyroid disease	1.1	0.26–4.74	0.885	—	—	—
MGFA classification	1.0	0.68–1.39	0.886	—	—	—
Bulbar involvement	1.1	0.44–2.50	0.908	—	—	—
Ocular involvement	1.3	0.17–9.34	0.819	—	—	—
History of myasthenic crisis	1.1	0.44–2.15	0.959	—	—	—
Preoperative plasmapheresis	0.6	0.31–1.24	0.181	—	—	—
Time to surgery	1.0	0.99–1.02	0.254	—	—	—
VATS approach	0.6	0.30–1.40	0.268	—	—	—
Preoperative mestinon doses	1.0	0.99–1.01	0.181			
Preoperative prednisolone doses	1.0	0.97–1.01	0.412			
Preoperative azathioprine doses	1.0	0.98–1.01	0.211			

CI = confidence interval; DM = diabetes mellitus; HR = hazard ratio; MGFA = Myasthenia Gravis Foundation of America; VATS = video-assisted thoracoscopic surgery.
[a] Stratified by propensity score.

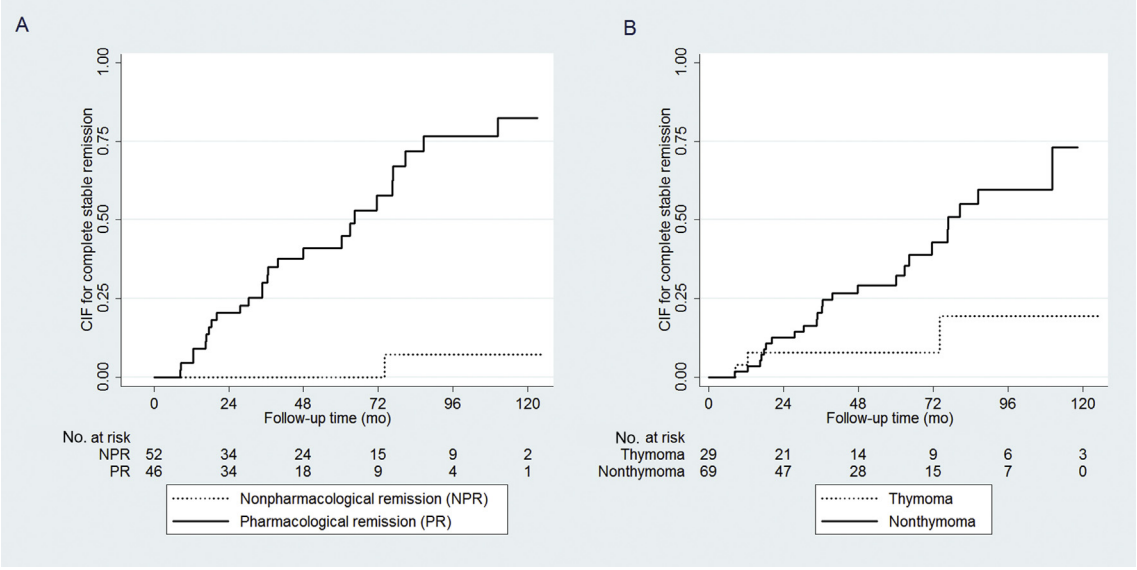

Figure 2 Cumulative incidence function (CIF) of complete stable remission stratified by: (A) pharmacological remission (*p* value 0.002); and (B) thymoma ($p = 0.049$).

Regarding the neurological outcomes, and the rate of CSR, this study showed that thoracoscopic thymectomy was comparable to trans-sternal thymectomy, consistent with some previous studies.[18,39] Other neurological outcomes such as the rate of reduced medication and pharmacological remission were not different as well. Although there was no statistically significant difference in term of CSR between the two approaches, the trend of CSR in the thoracoscopic thymectomy group was higher than in the trans-sternal thymectomy.

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In this study, CSR rate in the thoracoscopic group at 96 months (8 years) was 60.4%, whereas it was 75% at the 10-year follow-up in the study by Manlulu et al.[40] Jaretski et al[8] reported a CSR of 62% at 7.4 years and Lui et al[33] demonstrated a CSR of 47% at 60 months. The CSR rate after thymectomy via the right thoracoscopic approach in our study is comparable to previous studies. However, a longer follow-up time is needed to evaluate the neurological outcomes with this approach.

The predictive factors of CSR are still inconclusive.[41] Our results demonstrated two independent predictive factors for CSR after thymectomy: nonthymoma and PR. Patients who were diagnosed with nonthymoma had 3.5 chances to achieve CSR compared with thymoma patients. Many previous studies reported the same result.[27,29,30,42,43] A nonthymoma diagnosis is one of the prognostic factors for achieving CSR, although the result was not confirmed by the analysis stratified by PS. The possible reason is a mask effect from stratified with PS. According to the definition of CSR and PR,[19] patients who had PR were those with no symptoms or signs of MG for at least 1 year while they were still taking medications. Not all patients who had PR will eventually experience CSR: in our study, 43.5% of patients who had PR did not present with CSR. Therefore, PR was included as one of the possible prognostic variables in the multivariable model. PR has never been previously reported as a predictive factor for CSR after thymectomy in MG patients. However, it is the strongest predictive factor in this study. An age younger than 50 years has been reported as one of predictive factors for CSR[30]; however, we found that an age younger than 40 years was a predictive factor for CSR in univariable analysis but not in multivariable analysis. This result could be explained by insufficient statistical power.

The limitation of this study is the retrospective nature of data collection and the short follow-up time. There may be some selection bias or confounders by indication as described above. Because of the small sample size, competing risk analysis among CSR, loss at follow-up, and death was not performed. The CSR rate might be slightly overestimated.

5. Conclusion

Thymectomy via the right thoracoscopic approach is a good optional treatment for MG patients because it is less invasive than the standard technique, has a decreased length of hospital stay, and comparable neurological outcomes to the trans-sternal approach. However, prospective randomized controlled trials with a longer follow-up time are warranted.

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